Project of Strategic Interest NEXTDATA

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Report of the measurement campaigns

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Summary

Ion composition during new particle nucleation events at the Pyramid Laboratory in Nepal (APiTOF in Nepal).... 3
The QA/QC campaign at Lukla 6
The QA/QC campaign at Pyramid-AWS1 10
Description of the parameters used for QA/QC result assessment 13

Bibliographic references: YU S., EDER B., DENNIS R., CHU S.-H. and SCHWARTZ S.E, (2006): New unbiased symmetric metrics for evaluation of air quality models. *Atmospheric Science Letters,* 7(1), 26–34.

Ion composition during new particle nucleation events at the Pyramid Laboratory in Nepal (APiTOF in Nepal)

RESEARCH COORDINATOR: Federico Bianchi (PSI-Paul Scherrer Institute, ETHZ-Eidgenössische Technische Hochschule Zürich)

LOCATION: Pyramid International Laboratory (Nepal)

INVOLVED RESEARCHERS: Federico Bianchi, Heikki Junninen (University of Helsinki)

OBJECTIVES OF THE CAMPAIGN: Atmospheric aerosol can affect the climate directly by absorbing and scattering the light and also indirectly acting as a Cloud Condensation Nuclei (CCN). Formation of new particles from trace gases (nucleation) is the main source of aerosol in the atmosphere (Kulmala, 2004). Once the particles are formed they can grow and some of them reach the size of cloud condensation nuclei (CCN). It has been estimated that nucleation may be responsible for the formation of up to 50% of the total CCN concentration (Merikanto, 2009). Despite the importance of the process and the number of studies focusing on this topic, the mechanism of nucleation is still highly uncertain especially at high altitude. There is growing evidence that the main precursor of this process is sulphuric acid that is produced by the photo-oxidation of sulphur dioxide. On the other hand, the Cosmics Leaving OUtdoor Droplets (CLOUD) experiment demonstrated that sulphuric acid alone or together with ammonia cannot explain nucleation and growth rates observed in the planetary boundary layer (Kirkby, 2011).
To understand the nucleation mechanism, it is fundamental to know sulphuric acid concentration, chemical clusters composition of the ions, to determine nucleation rate and the growth extremely precisely and to know the ions size distribution. The main objective of the Project is to study new particle formation at high altitude with a focus on the chemical composition of the freshly formed clusters. The mechanism of new particle formation (NPF) events is still poorly understood. It has been observed that nucleation take place all around the world but the main observations are taken in the planetary boundary layer (PBL). By this Project, nucleation was investigated in the free troposphere at the Pyramid station in Nepal. The condition to study this phenomena at the Pyramid are unique: high altitude, pristine area and relatively far away from any strong sources of pollution.
For this Project, an Atmospheric pressure interface Time-of-Flight mass spectrometer (APiTOF) was deployed to the Pyramid Laboratory. This instrument has a really high resolution (>5000 Th/Th) able to retrieve the chemical composition of the growing clusters up to 2000 Th. This is a new instrument (Junninen, 2010) and at the moment only the University of Helsinki and the Paul Scherrer Institute can provide it for this kind of measurements.

KULMALA M. ET AL., (2004): Formation and growth rates of ultrafine atmospheric particles: a review of observations. *Journal of Aerosol Science* 35, 143.

MERIKANTO J., SPRACKLEN D V.,. MANN G. W,. PICKERING S. J,. CARSLAW K. S, (2009): Impact of nucleation on global CCN. *Atmos. Chem. Phys*. 9, 8601.

KIRKBY J. ET AL., (2011): Role of sulphuric acid, ammonia and galactic cosmic rays in atmospheric aerosol nucleation. *Nature*, 476, 429.

JUNNINEN H. ET AL., (2010): A high-resolution mass spectrometer to measure atmospheric ion composition. *Atmos. Meas. Tech.* 3, 039-1053

PERIOD: From the 25th of November until the 26th of December 2014

INVOLVEMENT OF NEXTDATA RESEARCHERS: Gianpietro Verza (URT Ev-K2-CNR); Angela Marinoni (ISAC-CNR); Paolo Cristofanelli (ISAC-CNR); Paolo Bonasoni (ISAC-CNR), Kaji Bista, Laxman Ahikary, Tenzing Sherpa, Pema Sherpa, Lakpa Tshering Sherpa, Lakpa Tenzing Sherpa, Dorjee Tamang, Tshering Dorjee, Sonam Tharke, Dawa Tshering, Sonam Tashi (Pyramid Technicians).

ON SITE ACTIVITIES: The main activity carried out at the Pyramid was to collect as much data as possible to properly understand the nucleation process at high altitude in the Himalayan region. Due to problems with the local administration, the field campaign has been delayed from Spring to Autumn 2014. During the field campaign, main activities included the installation of state-of-the-art instruments (see section below) as well as a continuous check to verify that the instruments were running properly during the whole campaign period. This was done checking on a daily basis all the most important parameters for each instrument.
URT Ev-K2-CNR staff handled the complex logistic activities connected with the experimental campaign (transport of personnel and equipment, installation of the experimental set-up). For the campaign more than 300 kg of equipment have been sent to the Pyramid Laboratory. Particular attention has been devoted to link the new instrumentation to the Pyramid and NCO-P systems with the purpose of providing continuous and stable power and internet connection. URT Ev-K2-CNR provided information about weather conditions and air-mass transport regime along the Khumbu valley by sharing the data from the AWS network. Daily information about the occurrence of special events (i.e. open fires) was also provided to the host scientists. ISAC-CNR and CNRS provided information on atmospheric composition variability by sharing near-real time data on SO_2 concentration and aerosol size distribution by SMSPS.

INSTRUMENTATION USED:
- Atmospheric pressure interface time-of-flight mass spectrometer (APiTOF) – Paul Scherrer Institute.
- Chemical ionization APi-TOF (CI-APi-TOF) – Paul Scherrer Institute.
- Particle size magnifier (PSM) – University of Helsinki.
- Neutral air ions spectrometer (NAIS) – University of Helsinki.

PRELIMINARY RESULTS: As already mentioned in this report, the measurement campaign took place in November-December 2014. After the installation, the three instruments have been checked on a daily basis to guarantee the collection of high quality data. Though being the most critical instrument, the APiTOF allowed to identify the chemical composition of the ions that are present in the high troposphere. The data analysis is still preliminary, but it is clearly showing that, for the first time in the world, a dedicated instrument for studying nucleation processes has been installed at such an altitude (5050 m.a.s.l.) and has collected reliable data.
Many nucleation events have been monitored with all the three instruments; during these events the chemical composition of positive and negative ions have been measured. More data analysis is still needed before any conclusions can be drawn.

CONTINAUTION OF ACTIVITIES: At the moment the researchers involved in that campaign are mainly working on the analysis of the data collected at the Pyramid. The plan is to publish a research article before the end of the year. Looking at the data will also help to understand if

there is the need of performing another campaign at the Pyramid eventually installing new/more instruments.

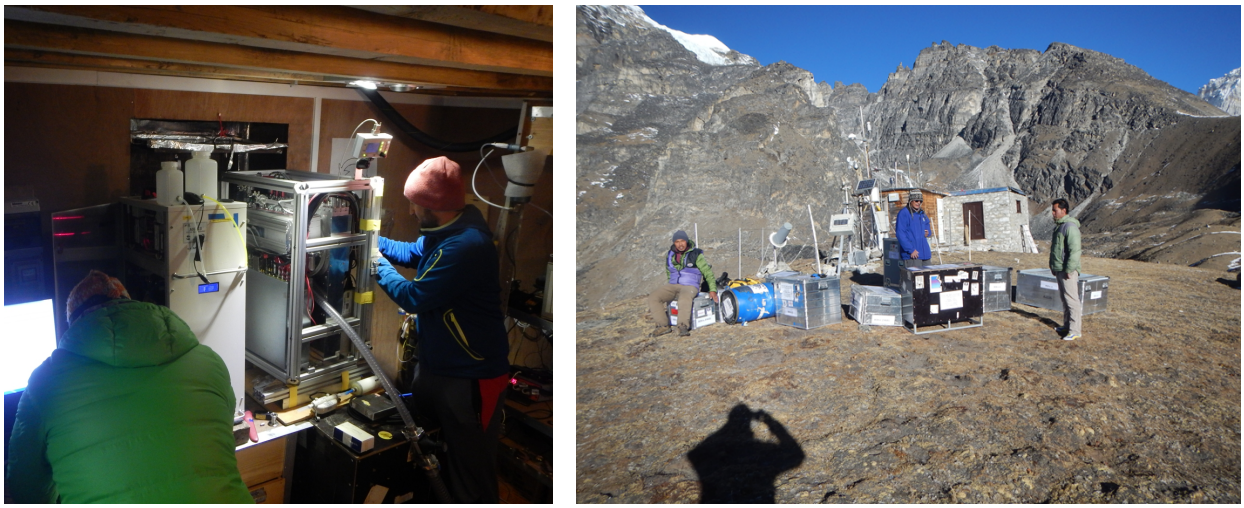


Fig. 1. On the left: PSI/ETHZ and Helsinki University personnel working on the experimental set-up. On the right: field campaign materials at the station.

The QA/QC campaign at Lukla

RESEARCH COORDINATOR: Giacomo Agrillo (ISAC-CNR).

LOCATION: Pyramid International Laboratory (Nepal).

INVOLVED RESEARCHERS: Paolo Cristofanelli, Giacomo Agrillo (ISAC-CNR); Gianpietro Verza, Elisa Vuillermoz (URT EV-K2-CNR); Daniela Meloni (ENEA-UTMEA).

OBJECTIVES OF THE CAMPAIGN: The main objective of the campaign is to assess the data quality of the Pyramid AWS and to identify possible instrument malfunctioning.

PERIOD: June, 6th - 27h, 2014.

INVOLVEMENT OF LOCAL RESEARCHERS: Gianpietro Verza (URT Ev-K2-CNR), Kaji Bista, Laxman Ahikary, Tenzing Sherpa, Pema Sherpa, Lakpa Tshering Sherpa, Lakpa Tenzing Sherpa, Dorjee Tamang, Tshering Dorjee, Sonam Tharke, Dawa Tshering, Sonam Tashi (Pyramid Technicians).

INSTRUMENTATION USED: AWS-QC.

RESULTS: During the year 2014, intercomparisons have been scheduled for the Khumbu Valley AWSs, in order to guarantee good quality meteorological and radiometric measurements, as already done since 2011.

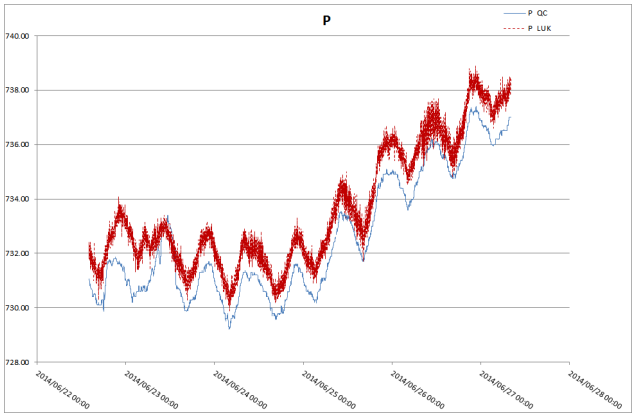
In this document the quality mission at the Lukla AWS is summarised.

The AWS-QC (Automatic Weather Station-Quality Control) was located near the Lukla AWS (2,660 m a.s.l.) from June 6th to June 27th.

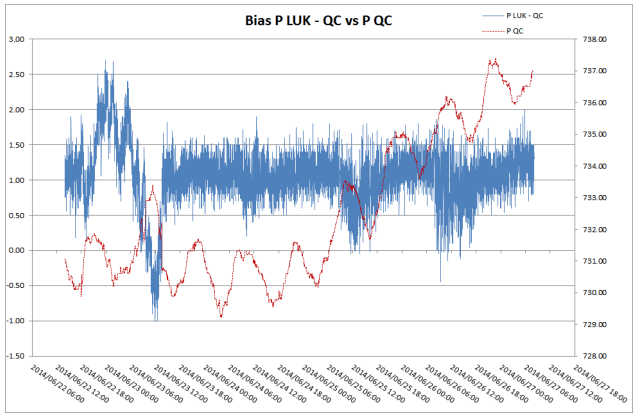
The AWS-QC power batteries had problems during the charging phase preventing operations during nighttime from the 6th to the 11th of June On June 12th, a new battery was installed to the AWS-QC. For these reason, the QA/QC has been carried out only over the period 22nd – 27th of June. In the following, the meteorological analyses performed during those are reported. On June 27th we decided to stop the QA/QC campaign because the monsoon season was approaching; any other possible interventions on the Lukla AWS were therefore postponed.

As for 1-minute atmospheric pressure (P) measurements, a systematic overestimation was observed with respect to AWS-QC. This was accompanied by an overestimation of the diurnal cycle amplitude. As for Temperature (T) and Relative Humidity (RH) measurements, the differences between AWS-QC and the Lukla AWS are generally lower, but some drifts are however noticeable in correspondence with the most rapid variations.

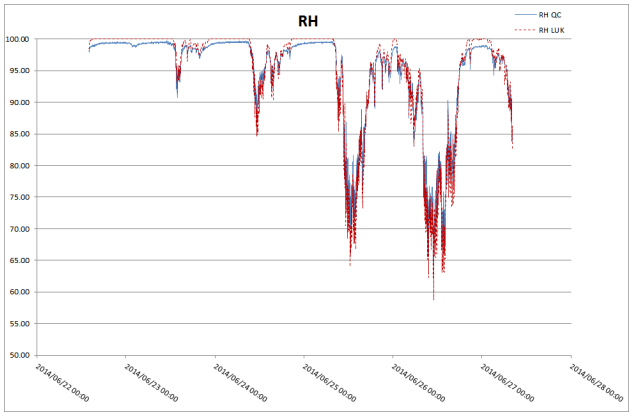
However, the main issues appeared to be related to wind measurements, as reported in Table 1.



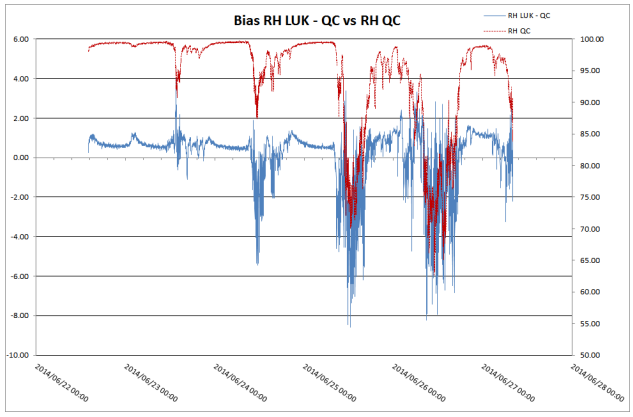
Pressure AWS-QC (blue line) and AWS Lukla (red line) – 22/06/27/06 2014



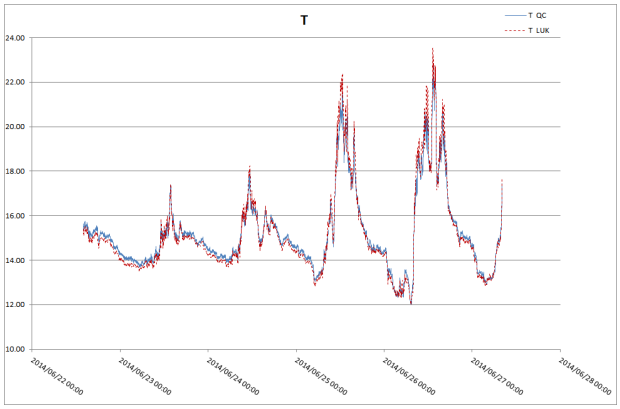
Pressure bias AWS Lukla - AWS-QC (blue line) versus Pressure AWS-QC (red line) – 22/06/27/06 2014



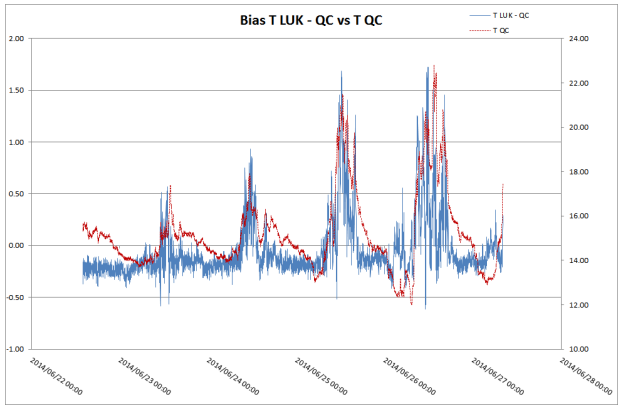
Relative Humidity AWS-QC (blue line) and AWS Lukla (red line) – 22/06/27/06 2014



Relative Humidity bias AWS Lukla - AWS-QC (blue line) versus Relative Humidity AWS-QC (red line) – 22/06/27/06 2014



Temperature AWS-QC (blue line) and AWS Lukla (red line) – 22/06/27/06 2014



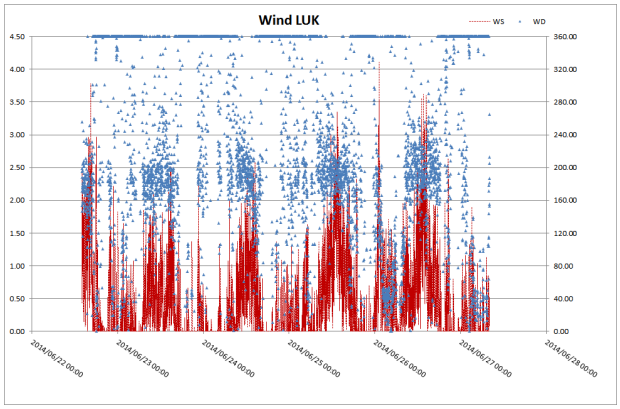
Bias AWS Lukla - AWS-QC (blue line) versus Temperature AWS-QC (red line) – 22/06/27/06 2014

LUK						AWS_QC				
	AP	AT	RH	WS	WD	AP	AT	RH	WS	WD
Avg	733.63	15.15	94.97	0.44	247.04	732.58	15.20	94.82	0.44	173.88
StDev	2.26	1.96	8.47	0.61	107.78	2.27	1.76	7.41	0.39	78.21
Perc25	731.90	13.95	94.44	0.00	174.00	730.67	14.14	94.35	0.17	119.73
Perc50	732.80	14.70	99.19	0.14	226.00	731.65	14.86	98.38	0.25	187.55
Perc75	735.80	15.54	100.00	0.69	360.00	734.80	15.62	99.33	0.63	213.40
Corr	0.98	0.99	0.99	0.77	0.24					
Mean Bias	1.05	-0.05	0.15	0.00	37.94					
RMSE	1.13	0.29	1.45	0.40	77.39					
MAGE	1.07	0.21	1.05	0.29	54.57					

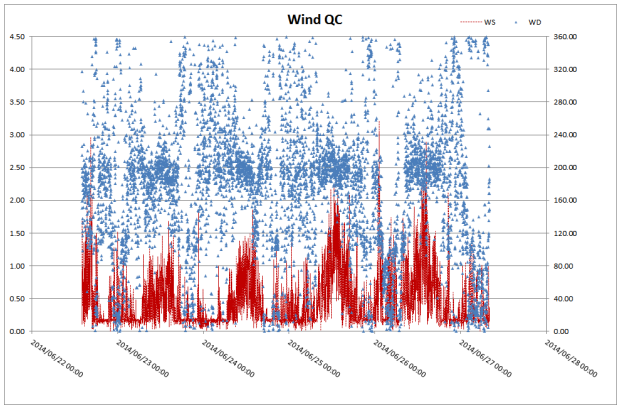
Tab. 1. Statistical indicator calculated between June 22nd and June 27th 2014. The following notations have been used: AP for Atmospheric Pressure, AT for Atmospheric Temperature, RH for Relative Humidity, WS for Wind Speed, WD for Wind Direction. Moreover, Avg stands for Average, StDev for Standard Deviation, Perc25 for 25th percentile, Perc50 for 50th percentile, Perc75 for 75th percentile, Corr for Correlation, RMSE for Root Mean Square Error and MAGE for Mean Absolute Gross Error.

Among the parameters described in Table 1, the Mean Bias gives an indication on how much the AWS measurements overestimate/underestimate AWS-QC observations; RMSE represents the standard deviation of the differences between values measured by AWS and AWS-QC; MAGE is a measure which provides information about the agreement between AWS and AWS-QC measurements For all these parameters, the perfect agreement should be indicated by values equal to zero. A definition of the used statistical parameters is reported at the end of this document.

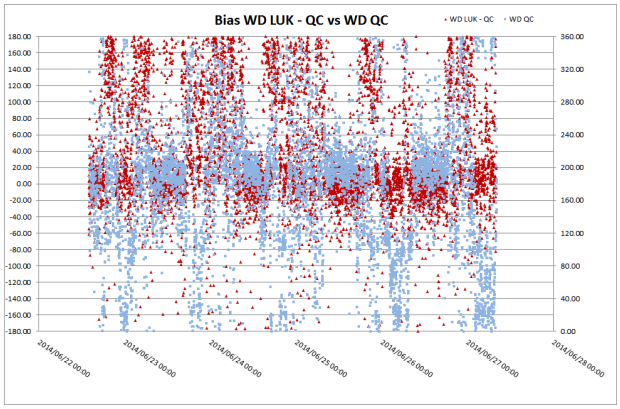
As shown in Table 1, the Mean Bias, RMSE and MAGE for wind direction (WD) were high, indicating a not satisfactory agreement between AWS-QC and the Lukla AWS observations. The low correlation value for this parameter also might also suggest that wind direction measurements are likely unreliable. The main differences in wind direction have been observed for wind speed low regimes, when wind direction presented a fix value (360°).



WS and WD AWS Lukla – 22/06/27/06 2014



WS and WD AWS-QC – 22/06/27/06 2014



Wind Direction bias AWS Lukla - AWS-QC (red dot) versus Wind Direction AWS-QC (blue dot) – 22/06/27/06 2014

Moreover, the data analysis indicated that Lukla AWS underestimated the wind speed at lower regimes and overestimated the wind gusts. It is likely that the large number of measurements with a fix value of 360° was related to the use of an old data-logger (Lastem Babuc) to record AWS data. The acquisition software of the data logger appeared to "cut off" low wind speed, recording these values as 0 m/s and wind directions as 360°.

However, as anticipated in this document, since monsoon was approaching and the operating conditions were becoming difficult, every decision about sensor or programming logger changes was postponed.

The QA/QC campaign at Pyramid-AWS1

RESEARCH COORDINATOR: Giacomo Agrillo (ISAC-CNR).

LOCATION: Pyramid International Laboratory (Nepal).

INVOLVED RESEARCHERS: Paolo Cristofanelli, Giacomo Agrillo (ISAC-CNR); Gianpietro Verza, Elisa Vuillermoz (URT EV-K2-CNR); Daniela Meloni (ENEA-UTMEA).

OBJECTIVES OF THE CAMPAIGN: The main objective of the campaign is to assess the data quality of the Pyramid AWS and to identify possible instrument malfunctioning.

PERIOD: November, 19th - 30th, 2014.

INVOLVEMENT OF LOCAL RESEARCHERS: Gianpietro Verza (URT Ev-K2-CNR), Kaji Bista, Laxman Ahikary, Tenzing Sherpa, Pema Sherpa, Lakpa Tshering Sherpa, Lakpa Tenzing Sherpa, Dorjee Tamang, Tshering Dorjee, Sonam Tharke, Dawa Tshering, Sonam Tashi (Pyramid Technicians).

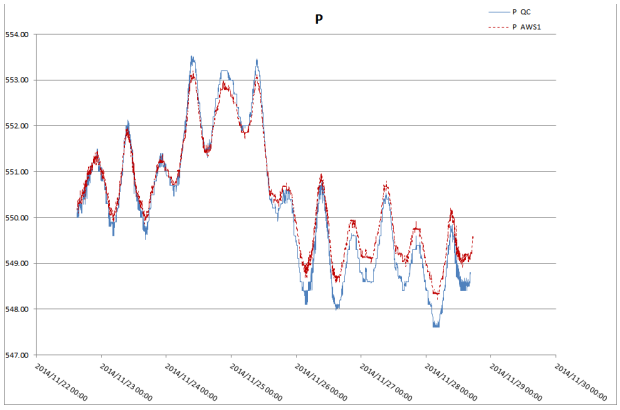
INSTRUMENTATION USED: AWS-QC

RESULTS: During the year 2014, intercomparisons have been scheduled for the Khumbu Valley AWSs, in order to guarantee good quality meteorological and radiometric measurements, as already done since 2011.

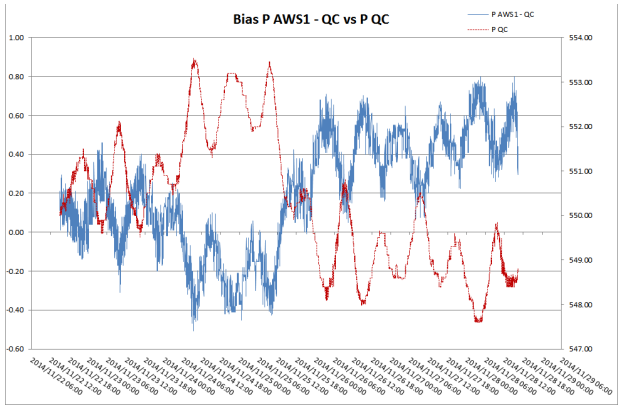
In this document the quality mission at Pyramid for the AWS1 is summarized.

The AWS-QC (Automatic Weather Station-Quality Control) was installed near the AWS1 from November 19th to November 30th, 2014. The period analyzed in this document is November 22nd – 28th.

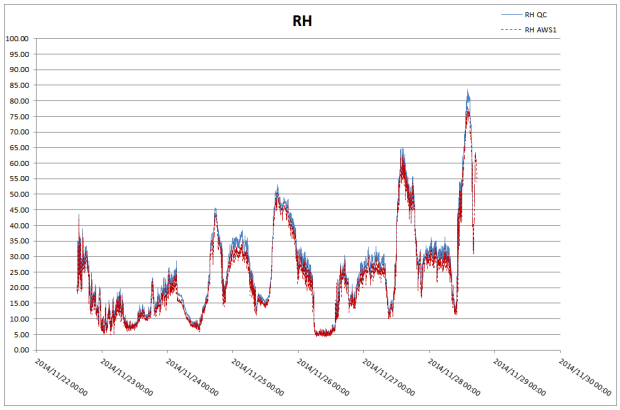
An overall good agreement between AWS-QC and AWS1 has been observed, leading to the conclusion that sensor replacement was not necessary for AWS1. In the following, some figures and statistical indicators are reported that summarize the main results.



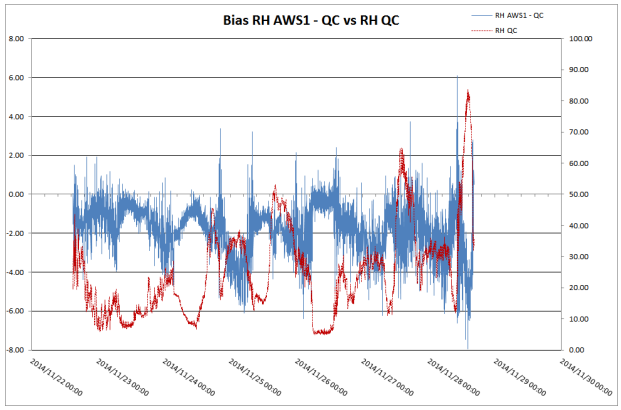
Pressure AWS-QC (blue line) and AWS1 (red line) – 22/11 – 28/11 2014



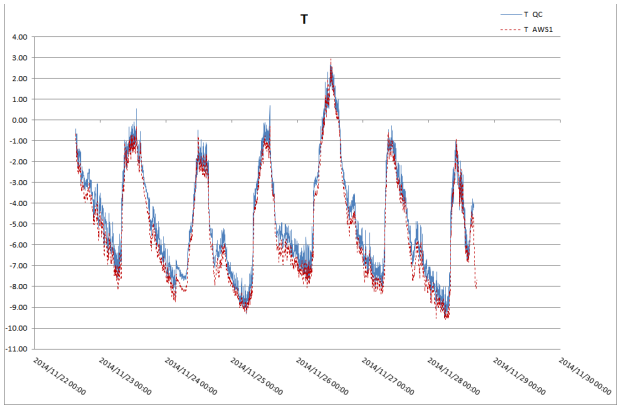
Pressure bias AWS1 - AWS-QC (blue line) versus Pressure AWS-QC (red line) – 22/11 – 28/11 2014



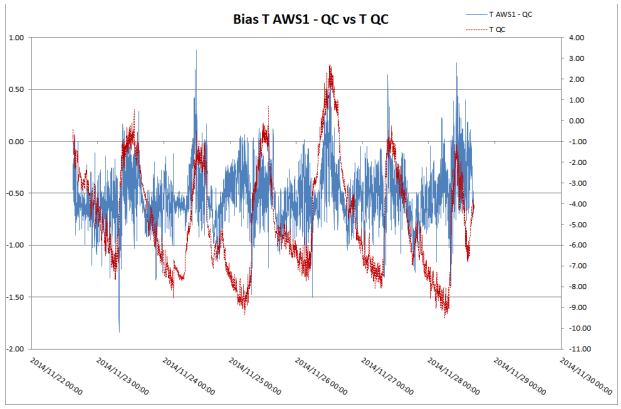
Relative Humidity AWS-QC (blue line) and AWS1 (red line) – 22/11 – 28/11 2014



Relative Humidity bias AWS1 - AWS-QC (blue line) versus Relative Humidity AWS-QC (red line) – 22/11 – 28/11 2014



Temperature AWS-QC (blue line) and AWS1 (red line) – 22/11 – 28/11 2014



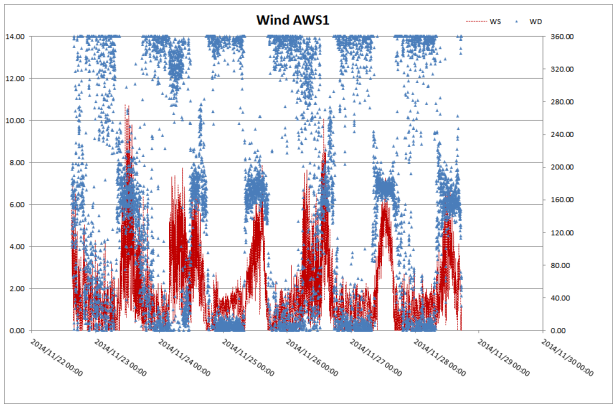
Bias AWS1 - AWS-QC (blue line) versus Temperature AWS-QC (red line) – 22/11 – 28/11 2014

AWS1						AWS_QC				
	AP	AT	RH	WS	WD	AP	AT	RH	WS	WD
Avg	550.49	-5.23	23.39	1.96	181.93	550.29	-4.71	25.20	2.16	200.57
StDev	1.22	2.65	14.14	1.68	129.53	1.50	2.58	14.76	1.64	117.39
Perc25	549.42	-7.40	12.80	0.74	48.64	548.95	-6.80	14.00	0.99	121.14
Perc50	550.45	-5.99	21.17	1.49	170.64	550.22	-5.27	23.03	1.78	174.70
Perc75	551.29	-3.21	29.58	2.82	330.25	551.30	-2.70	32.23	3.01	327.13
Corr	1.00	1.00	1.00	0.95	0.34					
Mean Bias	0.20	-0.52	-1.80	-0.19	17.16					
RMSE	0.35	0.59	2.19	0.56	33.98					
MAGE	0.30	0.54	1.85	0.40	20.24					

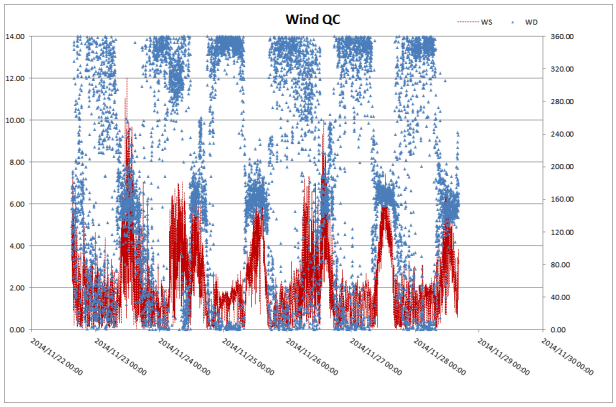
Tab. 2. Statistical indicator calculated between 22/11 – 28/11 2014. The following notations have been used: AP for Atmospheric Pressure, AT for Atmospheric Temperature, RH for Relative Humidity, WS for Wind Speed, WD for Wind Direction. Moreover, Avg stands for Average, StDev for Standard Deviation, Perc25 for 25th percentile, Perc50 for 50th percentile, Perc75 for 75th percentile, Corr for Correlation, RMSE for Root Mean Square Error and MAGE for Mean Absolute Gross Error.

As shown in the previous figures, for AWS1 only the barometric sensor seemed to show some underestimations of the field variation. However these differences are within the accuracy of the AWS1 barometer (±1 hPa).

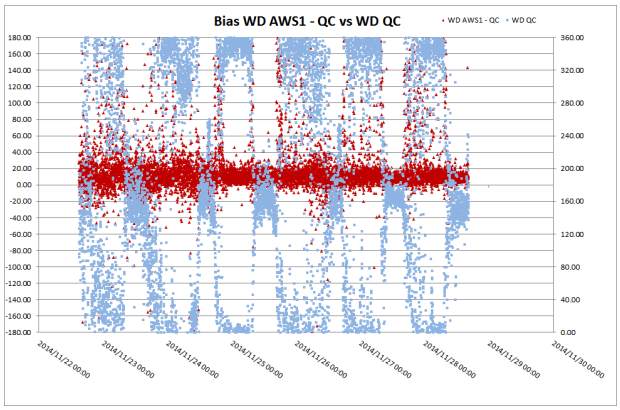
As for temperature and relative humidity measurements, some drifts are noticeable, but only in correspondence with the most rapid variations of both parameters. In general, the differences between AWS1 and AWS-QC are not dependent on the diurnal cycle of the fields and all statistical indicators indicate a good agreement between AWS1 and AWS-QC.



WS and WD AWS1 – 22/11 – 28/11 2014



WS and WD AWS-QC – 22/11 – 28/11 2014



Wind Direction bias AWS1 - AWS-QC (red dot) versus Wind Direction AWS-QC (blue dot) – 22/11 – 28/11 2014

As shown in Table 1 the worst agreement between AWS-QC and AWS1 was observed for the Wind Direction. However from wind direction analyses, a mean difference of about 20° between the two AWSs can be assessed. This could be attributed to the positioning of the two stations that was not exactly the same. The typical soil roughness of the rugged mountainous terrain where AWS1 is located can lead to small differences in the wind field.

Description of the parameters used for QA/QC result assessment

Parameter and Mathematical Expression	*Meaning*
$\text{Mean Bias} = \frac{1}{N}\sum_{i=1}^{N}(M_i - O_i)$	The mean difference between an estimator's expectations and the "true value" of the parameter being estimated
$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}(M_i - O_i)^2\right]^{1/2}$	The sample standard deviation of the differences between "predicted values" (the measures of the Lukla AWS) and observed values (the measures of the AWS-QC)
$MAGE = \frac{1}{N}\sum_{i=1}^{N}\lvert M_i - O_i\rvert$	The average of the absolute errors between the "predictions" (the measures of the Lukla AWS) and the "true value" (the measures of the AWS-QC)